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14. ABSTRACT The objective was to determine the optimal coagulation conditions for pre-treating laundry waste water before microfiltration (MF) when using the Army's Shower Water Reuse System (SWRS). In bench-scale tests, low doses of low molecular-weight epichlorohydrin/dimethylamine (epi/DMA) polymer produced the most rapid increase in zeta-potential, low specific resistance to filtration, low coefficient of compressibility, good removal of contaminants, and substantially decreased fouling of MF membranes. The critical flux was increased from 50 L m <sup>-2</sup> h <sup>-1</sup> for the control to 510 L m <sup>-2</sup> h <sup>-1</sup> for the CN condition, indicating the possibility of decreased footprint for the					
15. SUBJECT TERMS laundry wastewater, coagulation, membranes, ultrafiltration					
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a. REPORT UU	b. ABSTRACT UU	c. THIS PAGE UU	UU		Brian Dempsey
					19b. TELEPHONE NUMBER 814-865-1226

## Report Title

Final Report - Coagulation & Ultra-filtration of Laundry Waste Waters using the Shower Water Reuse System (SWRS)

### ABSTRACT

The objective was to determine the optimal coagulation conditions for pre-treating laundry waste water before microfiltration (MF) when using the Army's Shower Water Reuse System (SWRS). In bench-scale tests, low doses of low molecular-weight epichlorohydrin/dimethylamine (epi/DMA) polymer produced the most rapid increase in zeta-potential, low specific resistance to filtration, low coefficient of compressibility, good removal of contaminants, and substantially decreased fouling of MF membranes. The critical flux was increased from 50 L m<sup>-2</sup>h<sup>-1</sup> for no coagulant to 510 L m<sup>-2</sup>h<sup>-1</sup> for the CN condition, indicating the possibility of decreased footprint for the mobile treatment unit. Multi-cycle tests (up to 15 cycles of MF operation followed by backwashing) confirmed that hydraulic cleaning removed fouling when the system was operated with sub-critical flux. Full-scale tests with the SWRS demonstrated easy application of the epi/DMA polymer under field conditions, good removal of contaminants from laundry waste water, and negligible fouling of the MF. Additional tests showed that dead-end filtration (as used in the SWRS) resulted in less fouling than cross-flow filtration for laundry waste water, especially for operating times used in the SWRS between hydraulic cleanings.

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**Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:**

**(a) Papers published in peer-reviewed journals (N/A for none)**

<u>Received</u>	<u>Paper</u>
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**TOTAL:**

**Number of Papers published in peer-reviewed journals:**

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**(b) Papers published in non-peer-reviewed journals (N/A for none)**

<u>Received</u>	<u>Paper</u>
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**TOTAL:**

**Number of Papers published in non peer-reviewed journals:**

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**(c) Presentations**

Number of Presentations: 0.00

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**Non Peer-Reviewed Conference Proceeding publications (other than abstracts):**

<u>Received</u>	<u>Paper</u>
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**TOTAL:**

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

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**Peer-Reviewed Conference Proceeding publications (other than abstracts):**

<u>Received</u>	<u>Paper</u>
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12/19/2013	4.00	Hyun-Chul Kim, Xia Shang, Jin-Hui Huang, Brian A. Dempsey. Reuse of Laundry Wastewater using the Shower Water Reuse System (SWRS) with Added Coagulation, National Defense Industrial Association's (NDIA's) annual Environment, Energy Security, & Sustainability (E2S2) Symposium. 21-MAY-12, . : ,
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**TOTAL: 1**

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

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**(d) Manuscripts**

<u>Received</u>	<u>Paper</u>
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12/19/2013	1.00	Hyun-Chul Kim, Xia Shang, Jin-Hui Huang, Brian A. Dempsey. Treating laundry waste water: Cationic polymers for removal of contaminants and decreased fouling in microfiltration, Journal of Membrane Science (11 2013)
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12/19/2013	2.00	Xia Shang, Hyun-Chul Kim, Jin-Hui Huang , Brian A. Dempsey. Coagulation strategies to decrease fouling and increase critical flux and contaminant removal in microfiltration of laundry wastewater, Journal of Membrane Science (12 2013)
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**TOTAL: 2**

Number of Manuscripts:

Books

Received      Paper

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	Discipline
Xia Shang	1.00	
<b>FTE Equivalent:</b>	<b>1.00</b>	
<b>Total Number:</b>	<b>1</b>	

Names of Post Doctorates

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	
Hyunchul Kim	0.25	
Jinhui Huang	0.00	
<b>FTE Equivalent:</b>	<b>0.25</b>	
<b>Total Number:</b>	<b>2</b>	

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	National Academy Member
Brian Dempsey	0.15	
<b>FTE Equivalent:</b>	<b>0.15</b>	
<b>Total Number:</b>	<b>1</b>	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>	Discipline
Ryan Singer	0.05	Civil Engineering
<b>FTE Equivalent:</b>	<b>0.05</b>	
<b>Total Number:</b>	<b>1</b>	

### Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: ..... 1.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 1.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 1.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense ..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: ..... 0.00

### Names of Personnel receiving masters degrees

NAME

Xia Shang

**Total Number:** 1

### Names of personnel receiving PHDs

NAME

**Total Number:**

### Names of other research staff

NAME

PERCENT SUPPORTED

**FTE Equivalent:**

**Total Number:**

### Sub Contractors (DD882)

### Inventions (DD882)

## **Scientific Progress**

The following accomplishments were obtained as a result of this funding.

Laundry wastewater was treated at full-scale using the Army's Shower Water Reuse System (SWRS). This was the first time the SWRS was used to treat laundry wastewater. That portion of the work was conducted at Penn State University at a site adjacent to the PSU laundry.

Earlier bench-scale tests demonstrated the following:

- (a) high molecular-weight core-polymer quaternary amine polymers were optimal for treating laundry wastewater with solids separation by sedimentation;
- (b) low molecular weight (MW) Epi-DMA quaternary amine polymers were optimal for decreasing specific resistance to filtration and for applications in which coagulated solids are removed by low-pressure membrane filtration;
- (c) exact neutralization of the negative charge on laundry wastewater contaminants by the positive charge on cationic polymers resulted in the best removal of contaminants and the least membrane fouling;
- (d) the low MW Epi-DMA polymer was effective at removing contaminants and reducing fouling over a broad pH range, from neutral pH 7 to the very alkaline pH up to 12 of some laundry water;
- (e) the critical flux for microfiltration was increased by a factor of ten after addition of the CN coagulant dose to laundry wastewater, meaning that it would be possible to treat ten times as much laundry wastewater after coagulation compared to treating raw laundry wastewater;
- (e) streaming current detectors were effective at identifying the charge neutralization (CN) condition over the entire pH range and results were compatible with the more difficult and less field-friendly measurement of zeta potential (ZP);
- (f) the low MW epi-DMA polymer increased removal of contaminants and decreased fouling when applied at less than 50% of the CN dose, although improvements were not as great as with the CN dose;
- ((g) the low molecular weight epi-DMA polymer was easily prepared in the field and it retained coagulation effectiveness even after month-long storage at near-freezing to 40C conditions; and,
- h) the results reported in items d-g suggest that low MW Epi-DMA polymer provides a robust treatment strategy for use in challenging conditions where contaminant concentrations change with time and where personnel and instrumentation might not allow operation exactly at the CN condition;

## **Technology Transfer**